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Preliminary Assessment of the Physical State of the Old Cairo Structures

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Prepared for

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INTRODUCTION

During the period of February 13 to 19, 2001, the author performed a preliminary assessment of the area identified as Old Cairo, located in Cairo, Egypt. This evaluation was made at the request of Dr. Peter Reiss of Development Alternative Associates and USAID. Our scope of work as defined by the attached purchase order is provided for your reference. This report addresses all of the work requirements of the purchase order but in addition we have attempted to address the far more important and complex issues encountered during our investigation.

We conducted our analysis with the cooperation of many individuals including his excellency, Dr. Abdel Rehim Shehata, Governor of Cairo; Mr. James Harmon, Chief, Division of Water and Wastewater; USAID, Messrs. Peter Sheehan and Michael Jones of the American Research Center in Egypt (ARCE); Engineer Wafaa Faltous of USAID; Dr. Mona Zakariya of the Ministry of Tourism; Samia Banob, the project manager for the Cairo Wastewater Organization; Messrs. S. B. Gokhale and Rajan Patel of CCJM, the consulting engineers responsible for the design of the dewatering system for the project; Engineer Mohammed Hashem, General Manager of The Arab Contractors, the company required to implement the installation of the dewatering system; Engineer Mohammed Saad of Hamza Associates, the geotechnical consultant to the contractor; Father Gabriel of the Church of Saint Sergius; Dr. and Eng. Adel Fareed of Egy-Tech Group, consulting engineer to the Church of Saint Sergius; Theof ILaktos, the Bishop of Babylon and head of the Greek Orthodox Monastery of Saint George; and Drs. Bazaraa and Ghabrial of the University of Cairo acting as the engineering consultants to the Greek Orthodox Patriarchate of Alexandria and in particular providing geotechnical and structural engineering expertise for the Roman Tower and the Church of Saint George.

Our primary purpose was to provide a preliminary assessment of the physical state of the site, to provide an opinion of the current dewatering design system and its implementation, to review the current status of the work, and to offer solutions and advice in resolving issues of dispute and concern that have been voiced by a number of parties including Dr. Mona Zakariya, the Greek Orthodox Monastery and The Arab Contractors. Our secondary, but equally important purpose, was to provide the terms of reference for a more comprehensive investigation of the project.

Our statements of opinion are as follows:

A. Physical Description of the Old Cairo Site and the Ground Water Issues Affecting Its Long Term Survivability

The Old Cairo area exists within the Fortress of Babylon, a Roman site which dates from 300 AD. However, an earlier Pharonic settlement or temple most likely occupied the area; the author observed the reuse of Pharonic stonework on the lower southwest wall sections of the outer enclosure. Peter Sheehan, who is supervising the archaeological monitoring during construction of the dewatering system, has theorized that the somewhat dominating western towers are possibly associated with the location of a boat bridge across the Nile.

Throughout much of its existence, Old Cairo has been identified as a core of activity by Jewish, Coptic and Greek Orthodox religions. For approximately two centuries following the Arab Conquest of 641 AD, a period of building activity took place as the location assumed its position as the center of the newly founded Islamic City of Fustat. However, during the 10th century the center of power was transferred to what is today Historic Cairo. Following a series of political and economic disasters, the site was largely abandoned or destroyed by the 11th century but it remained as a pilgrimage location for Christians. During the 17th century there was a deliberate attempt by Coptic merchants to rebuild the area. Following the installation of the railway system adjacent to the site in the 1800's, the location was reunited with the rest of Cairo. At this time cemeteries were installed and the area's religious character was maintained. Extensive building and rebuilding programs continue to the present day, but a particular massive program was undertaken by the Greek Orthodox Church starting in 1882 with modifications in 1909 and 1941. Widespread filling within Old Cairo has been performed throughout its long period of occupation.

As a result, the structural and foundation characteristics of the buildings and their ancillary components within Old Cairo are extremely varied and complex. Modern elements exist adjacent to or above ancient structures. Structures may be supported on fill, ancient foundations or a combination of both. The quality of construction varies from good to extremely poor with newer work incorporating older intact or demolished portions of foundations, walls and columns. Evidence of continuing differential settlement is present throughout the site. All structural elements within the area should be considered as sensitive to any form of deformation.

Complicating this situation is the fact that the ground water level has risen throughout the entire area. There is evidence to suggest that one of the reasons for the filling discussed above was to deal with the rising water level of the Nile. Within the last 30 years, however, a dramatic change in water level has occurred that is believed to be primarily associated with the rapid expansion of population within the vicinity. The basements of a number of monuments within the Old Cairo area, namely the Church of Saint Sergius (Abu Serga on the attached plans), the Greek Orthodox Church of Saint George, the Hanging Church, and the Ben Ezra Synagogue are continually flooded. Others such as the Chaplet of Saint George and the Church of Saint Barbara are excessively damp. As observed by the author, the groundwater is also contaminated by sewage.

Faced with these conditions and the fact that at least two of the owners began to perform unfiltered pumping to alleviate the situation, a dewatering system, identified as Contract 102, was proposed by the Cairo Wastewater Association; the firm of C. C. Johnson & Malhotra (CCJM) was chosen to implement the design and the firm of The Arab Contractors was selected by bid to perform its required construction.

B. A Brief Description of the Dewatering System

The design as developed by CCJM utilizes a number of perforated shafts located at strategic locations, which are connected in series by micro tunnels. The shafts are surrounded by and are connected to what have been termed “secant piles”. These are not true secant piles as normally defined in construction; however, since this terminology has been employed on the drawings and has been accepted by the project, this report will refer to them as such. The secant piles are actually sand and gravel filters, which are used to prevent fine soil material from entering into the dewatering system; they are installed using equipment and similar procedures as normally employed in true secant pile work. Generally, linear protrusions of the secant piles extend outward from the shafts in order to increase the effective collector surface area. Although this is the first time this particular approach has been used for dewatering, the author believes, based upon present information, that accepted engineering standards were used in its development.

Within Mar Girgis Church and the Roman tower, the system is supplemented by a somewhat more traditional subfloor drainage method utilizing horizontal perforated pipes enclosed within gravel and fabric filters. The pipes lead to a collector which in turn transfers groundwater to the main system.

Rather than attempting to reduce the groundwater level over the entire Old Cairo site, the system in its present configuration targets certain historic structures, namely, the Greek Orthodox Church of Saint George (Mar Girgis), the Roman Tower, the Church of Saint Sergius (Abu Serga), the Ben Ezra Synagogue, and the Coptic Church of Saint George. Under a separate non-USAID funded project, the Hanging Church will also be incorporated into the design. The plan of the system is shown on the attached Drawings 102 and 106.

C. The Author's Concerns With the Design and the Methods Which are Proposed to Address Them

No matter how perfectly designed or how well executed, any dewatering program undertaken in the Old Cairo area will produce settlements and subsequent cracking of the existing buildings. This fact needs to be more clearly stated to all owners within the area, not only those who are responsible for the significant monuments located on the site. The objective of an engineering design is to minimize anticipated deformations which will be produced. The author believes that the necessity for and the benefits of dewatering far outweigh local distortions that may take place.

Actual dewatering of the site has not yet begun as part of this contract. Although lowering the water table can mitigate the continual flooding of the area, the design and installation of the

drainage system must address certain engineering and construction issues. We evaluated the work based upon the following criteria:

C1. During installation unacceptable movements should not be generated within the soil mass upon which structures are founded.

We are not satisfied that this criterion was fully addressed by the design engineer, the contractor's geotechnical consultant, or the contractor. We base this conclusion on the following observations:

a. Perforated Shaft No. 5 was located in very close proximity to the structure identified as the Synagogue Annex on attached Drawing 102-6; the Annex is founded on a shallow foundation. During the installation of this shaft, an ancient wall was encountered. Upon removal of this obstruction, a relatively sudden ground subsidence occurred which was followed by settlements of and structural damage to the Annex.

b. We noted ground surface horizontal soil movements immediately adjacent to the northeast side of Ben Ezra Synagogue; we also observed similar deformations at the retaining wall immediately adjacent to the southeast face of Saint Sergius (Abu Serga on the plans). Furthermore, we recorded movements of the Annex building that we believe would not have resulted from the ground subsidence described above. We strongly suspect that since uncompacted sand filter material is used in this design, the secant pile system is behaving in a manner somewhat similar to a linear open cut excavation.

If this system is employed at other locations we would not recommend its use adjacent to shallow founded structures. Fortunately, the main body of the Saint Sergius Church, Ben Ezra Synagogue and Mar Girgis Church appear to be founded quite deeply; excessive settlements of these structures have not been recorded. Furthermore, the installation of the secant piles is now nearly complete and, in our opinion, additional deformations similar to those indicated above are not likely to occur.

We have also expressed concern to USAID's representative, Wafaa Faltous, and to the Engineer of Record, C. C. Johnson & Malhotra, P. C., that the installation of Shaft No. 1 and the perforated drain system within Mar Girgis Church should be undertaken only after the main dewatering system is operational and the pressure head near the church has been reduced. We believe that the potential for encountering quick conditions will be substantial if this precaution is not heeded.

C2. The dewatering system should not remove soil material from beneath the foundations of structures.

We are satisfied that the design engineer will implement safeguards to ensure that this criterion is met. Since the importance of this issue and the mechanics of the problem may not be fully understood by all parties, the following is an explanation of the process:

The structural elements of Old Cairo are most likely founded on fill containing clays or on a material identified as “very loose to medium dense silty sand or clayey sand”. That is, they are supported on soils of very fine particle size. Since the new drainage system may be installed below the base elevation of the foundations, the flow of water that is directed to the drains may carry with it these fine particles of silt and clay. The removal of fines usually progresses along the path of least resistance forming underground channels; the corresponding loss of ground associated with this phenomenon, known as piping, may be particularly important if it produces voids below the foundations of the monuments or adjacent structures. The presence of such voids could lead to differential settlements that would seriously damage the Old Cairo complex.

The installed drainage system employs sand and gravel materials as filters to prevent piping from taking place. However, such a system will be hidden from view after installation and any undetected deficiencies of construction may not produce noticeable effects until long after the drainage process begins. Considering the enormous value of the structures that may be potentially affected, the author highly recommends that the settlement monitoring program instituted by this project continue for at least two years following initiation of dewatering operations and that water removed from the area be continually examined for evidence of the presence of silt or clay particles.

C3. The dewatering process should not produce excessive differential settlements associated with the consolidation of the clay bearing strata.

A lowering of the water table will cause the hydrostatic pressure in the clay bearing strata to be reduced. This pressure reduction will cause the clay particles of soil to move closer together in a process known as consolidation. As a result, additional settlement of the structure may occur. Settlements produced as a result of consolidation are not immediate; they do not achieve their full magnitude until considerable time has passed. As an analogy, the clay may be thought of as a sponge saturated with water. If loads are applied to it, time is required for the water to squeeze out before full compression takes place.

The amount of consolidation likely to be produced is dependent on a number of factors including previous historic water levels and the past geologic conditions that may have "preconsolidated" the strata. However, the process is well known and reasonably accurate assessments of potential settlement can be calculated based upon geotechnical analysis of samples gathered during normal soil boring operations. Since this project utilizes a targeted approach to dewatering, differential settlements will be produced.

Mr. S. B. Gokhale stated that the total settlement is not expected to exceed 1 centimeter and that the differential settlements will be less than 1/1000; these are acceptable criteria if horizontal soil deformations are not excessive. Although a calculation check to verify these amounts is beyond the scope of this preliminary study, we are reasonably certain that the consolidation quantities stated by the engineer and contractor are accurate for the following reasons:

- a. The water table will be lowered only 2 to 2.5 meters in height. We would not classify this amount as an extreme lowering of the water table.

b. The soil strata below many of the monuments have undergone some form of consolidation from centuries of structural loading.

c. Our previous experience with dewatering operations at other sites leads us to believe intuitively that the consolidation settlement amounts should be low.

We therefore conclude, based upon a preliminary analysis, that the dewatering operations intended for this area should move forward subject to the conditions that are stated in our summary recommendations stated below.

D. Recent Developments

The following recent events have occurred which should be investigated as part of the comprehensive follow-up assessment:

1. On February 15, 2001, the author met with Drs. Bazaraa and Ghabrial, the consultants to the Greek Orthodox Church, to discuss the dewatering operations and their concerns with the operation. At that meeting it was clearly agreed by all parties that most of the cracks observed in the Church of Saint George (Mar Girgis) existed prior to any construction activities and that repairs to the church would have been required irrespective of the dewatering work. Dr. Ghabrial stated that “the church is in imminent danger of collapse”. We do not agree with the latter statement; however, similar information has been transmitted to the contractor for the project. Dr. Bazaraa stated that “the church will be sufficiently protected if the contractor installs protective measures such as banding, shoring and wall ties.” Dr. Bazaraa also indicated the dewatering is the first step necessary to begin the process of repairing the church.

On February 18, 2001 during a meeting with the Patriarchal Vicar of the Greek Orthodox Church the author was presented with a document entitled “*Report on the Cracks in the Buildings of St. George Church - Mar Girgis - Old Cairo*” by Drs. Bazaraa and Ghabrial of Cairo University. This report was transmitted personally to the author provided that “the use of any data, figures, photos enclosed in the report, and/or reproducing a photocopy of all/or part of this report, for any reason, is completely prohibited unless having a written permission of the Patriarchate.” We have the following comments concerning this report:

a. The report states that many cracks occur in the church and that they were formed many years ago; however, it emphasizes that they were recently activated by construction operations. Dr. Ghabrial stated to us that a number of cracks had stabilized prior to construction. We disagree with this statement based upon our own site analysis. We found no evidence to suggest that the cracks in the church will not continue to widen over the course of time.

b. The report indicates that there is evidence of recent differential settlement in direct proximity to the church. We agree, but, based upon present information we believe that these settlements were produced as a result of operations at the Hanging Church and not as part of the operations performed under Contract 102. We do not believe that excessive differential settlements were induced in the Church of Saint George.

c. The report states that “the church is susceptible to harmful consequences which may result in brittle fracture of the main church.” We are not certain how to interpret this wording but it is certainly an indication that the church is in poor condition.

d. Finally and perhaps most importantly the report states that “if, during or after the lowering [of the] ground water table in the church area according to Contract 102, monitored settlements and/or cracks become alarming, [the] work is to be stopped immediately in and around the church. Appropriate measures should be taken which may include supporting of certain elements, repair of cracks, grouting or using micro piles.” Our present understanding is that the Greek Orthodox Church believes that such measures, if required, should be performed by the contractor at his own expense; this would seem to be an unfair and unenforceable imposition.

During our meeting with the Church we continually emphasized that, given the poor condition of the structure, the Contractor should be held liable only for his negligent actions and not for repairs that are required to be performed as part of an anticipated repair and preservation program. This matter will require further discussion to resolve and clarify the issues of concern.

2. The Contractor appears to be aware of the Greek Orthodox Church’s position. Perhaps in response to it, Hamza Associates, the geotechnical consultant to the Contractor, has issued a revised assessment of the effects of the project on Mar Girgis Church. The consultant now indicates that the installation of the perforated drain and Shaft No. 1 should not begin until a complete restoration of the church and its auxiliary structures is complete. Since the conclusions arrived at by the consultant appear in part to be derived from rather unusual and perhaps erroneous settlement reports, further study, as part of the comprehensive follow-up assessment, should be performed concerning this matter.

If the ground water level at Mar Girgis Church is not lowered to the design-stipulated requirement, the benefits at this location and other areas may not be fully realized.

3. The Church of Saint Sergius (Abu Serga) has elected not to have a perforated drain installed in their structure as proposed on the contract drawings. Dr. Adel Fareed, the consultant to the church will design an alternative scheme that will tie into the dewatering system. Although we met with Dr. Fareed, he presented no drawings for our review. In his verbal description of his proposed work he stated that he would install a cutoff wall, which would extend to bedrock, around the crypt area of the building; the soil mass within the crypt would be dewatered independently of the rest of the church.

We are concerned that such a system would create a “hard point” within the structure making it more susceptible to differential settlements. When a design is presented, it should be subjected to a detailed review.

E. Additional Recommendations

Our additional recommendations are as follows:

1. Monitoring is key to the success of this project and to the protection of the structures that it may affect. Extremely unusual monitoring results have been recently presented by Hamza Associates that appear to indicate large stepped movements occurring between August and September, 2000. However, this information appears to have been only recently evaluated and discussed. This situation must be corrected at once.

Monitoring results must be interpreted and evaluated on a weekly basis by qualified personnel who can issue timely and clear reports that are understandable to all parties on this project. Required actions and recommendations should also be presented.

2. A pre-construction survey of the existing buildings does not appear to have been conducted. Such a survey documents every crack and deformation occurring in the structure before any work begins. It establishes a baseline for analysis of any further perceived or actual movements and is extremely useful in claims management. Since dewatering has not yet begun on this project, we believe that such a survey should still be undertaken at Saint Sergius Church, Ben Ezra Synagogue and Mar Girgis Church.

3. A detailed archaeological and architectural study must be carried out ahead of proposed installation of the subfloor drainage system in the church. ARCE, which is the most familiar with the church, should be funded to carry out this work.

4. The Hanging Church has instituted dewatering operations independent of this project that may influence structures within this contract. In order to determine the potential extent of this influence, elevation reference monitoring points should be established at the South Roman Tower, at the Antiquity and Museum Building and at the courtyard located east of the Roman Tower.

Additionally, an immediate liaison with all parties including USAID, the client, consultants and contractors for the Hanging Church and Contract 102, and the Ministry of Culture is required to ensure that the works of stabilization and dewatering are implemented safely, appropriately, and without damage to the existing structures. If permitted by the owners, a detailed engineering and geotechnical review of the Hanging Church drainage system and other ground-works to date should be undertaken.

Similarly, additional funding must be provided to ARCE in order to obtain a detailed archaeological and architectural analysis of the South Gate of the Roman fortress of Babylon as the first stage of the inclusion of this area within the proposed extended scope of Contract 102. Archaeological supervision and recording of the work being carried out for tile drain in the Roman gatehouse area beneath the Hanging Church must be implemented as soon as permissible. Archaeological monitoring of Contract 102 must be extended to cover proposed new shafts in the vicinity of the Hanging Church.

5. Many of the apparently modern buildings within the core area of Old Cairo incorporate elements of ancient structures but are not designated as monuments. They have therefore not been monitored, nor has the effect of the dewatering project on these structures (of largely

unknown but potentially widely differing foundation levels) been predicted. Currently a Ministry of Tourism-sponsored project directed by Dr. Mona Zakariya is carrying out a range of renovation work on many of these buildings. We therefore recommend the following actions:

- a. Meet regularly with Dr. Zakariya to enable her to consider the ongoing effects of construction and dewatering operations on structures within the project area.
 - b. Elevation reference points should be placed not only at the major monuments but should also be installed at every structure, including walls, likely to be affected by this contract. Based upon present information, the likely zone of influence should extend to 65 meters away from any collector point. The expansion of this zone should be determined on the basis of measurements taken and the prediction of effects of water drawdown on all buildings in the area. We recommend that Avongard Calibrated Tell-Tales be installed at significant cracks likely to be affected by the construction.
 - c. Begin a program of investigative test pits to be carried out in these areas (under ARCE archaeological supervision) to assess foundation levels and other relevant ground conditions.
 - d. Perform a geotechnical and structural engineering study of the likely impacts to these structures as part of a more detailed assessment of this project.
6. Greater understanding of the need for this project must be communicated to all building owners within the area. The potential effects of construction, which may include slight cracking, should also be discussed.
7. The insertion of a tile drain system below the floor of the 'crypt' of the church of Abu Serga has recently been proposed to the church authorities by CCJM. It is proposed to link this tile drain to Shaft No. 4 (already excavated) by deepening an existing trench in the southeastern side-chapel of the church. As requested by USAID the work will be carried out as part of the already approved Contract 102 and will involve initially the removal of the concrete floor inserted in the crypt during the 1980s. This location is perhaps one of the most sensitive on the entire project. Therefore, we recommend the following actions:
- a. Any subsequent excavation to enable the perforated pipes of the tile drain to be inserted should be carried out under ARCE supervision using approved archaeological methodology.
 - b. An overall plan for the complete conservation of the crypt church including the southern side chapel should be formulated, of which the dewatering provided by Contract 102 would form the initial element. Subsequent work will entail removal of damaging cement render, consolidation of the structure and other related work. This plan should be developed under the direction of ARCE and should be submitted to the church for discussion.
 - c. USAID, Father Gabriel representing Abu Serga, ARCE, and the Spanish conservation team currently working in fine art conservation in the church should set up a committee to resolve and discuss issues that affect the present and future preservation of the church as they relate to Contract 102. ARCE, which has already established good relations with the church, should lead this effort.

These recommendations will involve considerable effort on the part of ARCE and they should be funded accordingly.

8. Supplementary drainage works are also planned for the 'mikveh' and well area forming the basement at the eastern end of the Ben Ezra Synagogue. As currently proposed this will involve deep, shored excavations for the insertion of perforated drains to the east of the Synagogue, and the connection of these drains via the synagogue well with Shaft No. 5. Work in this area during the BES Restoration Project in the early 1990s indicated the presence of important archaeological deposits associated within the medieval community of the synagogue and the Roman fortress itself. We therefore recommend that ARCE be funded to perform the following work program at this location:

- a. A review of information concerning various foundation levels in the synagogue compound area should be undertaken.
- b. If required, investigative archaeological test pits should be carried out to supplement existing information.

This information should also be forwarded to USAID and the CCJM for their review and comment.

9. Safety at the site does not seem to be of high priority. On two occasions we observed children playing immediately adjacent to uncovered shafts. Safety is the contractor's total responsibility and if items such as this are not corrected in a timely fashion, we recommend that needed precautions be performed independently and that the cost of such work be deducted from the contract price.

10. The Engineer of Record's contract should be extended to provide for a maintenance contract with the Cairo Wastewater Organization to ensure that the system is properly monitored, particularly for the inspection for evidence of removal of fine soil particles.

11. Finally, detailed geotechnical, structural, and hydraulic studies are required to verify the initial conclusions made during our brief analysis. An independent and comprehensive second opinion of the present Contract 102 design with particular emphasis on the potential for damage to structures within the Old Cairo site should be obtained. This study should include a geotechnical, structural and, if required, hydraulic engineering analysis and should require a review of all available documentation including test borings, reports, monitoring results and other information that may be supplied by USAID. The reviewers should comment specifically on the two reports issued by Hamza Associates concerning their findings on Mar Girgis Church.

Because of the sensitive nature of this site and the monuments within it, we recommend that USAID anticipate that further review of the work will be required in order to evaluate dewatering systems being independently designed by building owners or alternate design and construction methods being proposed by the Engineer of Record and the Contractor. We understand that USAID's foremost concern is that such procedures are performed with the least intervention possible, and that they represent the least expensive, easiest alternatives that satisfy the original design intent. We therefore recommend that the team chosen to perform a second opinion also be assigned to continually advise and review the progress of this contract and the methods used

to implement it. ARCE should advise USAID on the composition of this team and on the potential need for commissioning short specialist studies as may be required on specific aspects of the work. Such a team should include an ARCE archaeologist as well as qualified structural and geotechnical engineers.

Old Cairo is a remarkable example of Egyptian heritage. The monuments within it are certainly worthy of any conservation effort that is undertaken to protect them. We have enjoyed working on this project and we look forward to the completion of a successful work program instituted for their continuing preservation.